Complete Concussion Management Inc.
Baseline Testing Protocol & Supporting Evidence

Purpose:

Resolution of symptoms following concussion is known to be a poor indicator of brain recovery. Concussion results in metabolic disturbance, changes in cerebral blood flow and perfusion, and a number of other pathophysiologic processes known as the *Neurometabolic Cascade* of concussion (1,2). Numerous studies show that prior to full metabolic recovery from a concussion, the brain is extremely vulnerable, where even smaller impacts can cause secondary concussion injuries and these injuries can result in severe brain injury with potentially permanent or fatal outcomes (3,4). The most important aspect to safe and proper management of concussions is to ensure that complete recovery of the brain has been achieved prior to allowing an athlete to return to a high-risk sport environment; a process which has been shown to take at least 3 to 4 weeks in adults and has an unknown timeline for children and adolescents (5-7).

Relying on the resolution of self-reported symptoms, to make return-to-play decisions puts healthcare practitioners in an extremely precarious position, as symptoms do not reflect true recovery of the brain following concussion. Self-reported symptoms at rest are even more unreliable as ongoing blood-flow and cognitive abnormalities may only come to light when challenged by intensive physical exertion tests (8-12).

Pre-season baseline testing involves testing high-risk athletes prior to starting their sporting season to assess numerous physical and cognitive systems that could potentially become affected by a concussion. When properly used and interpreted, baseline testing adds useful information to the management of sport-related concussion by giving clinical insight into pre-injury physical and cognitive functioning, which provides clinicians with objective data to make more informed, and therefore safer, return-to-play decisions(13).

It should be noted that baseline testing should involve more than just computerized neurocognitive measures. These measures are insufficient as stand-alone entities displaying numerous reliability and validity concerns. Additionally, these tests don't measure important aspects of concussion injuries such as balance, visual tracking and processing speed, strength & physical performance measures, auditory memory & concentration. A proper baseline assessment should involve all of these areas, **including** neurocognitive testing parameters.

This document covers all aspects of the Complete Concussion Management Inc. baseline testing protocol and provides evidence for each test included within our testing battery.

Overview of the CCMI baseline test protocol:

CCMI offers a service to physicians by conducting comprehensive preseason testing, as well as return-to-play management, multistage physical exertion tests, and re-testing of injured individuals. All of this information can be provided to the overseeing physician in a detailed report; providing additional insight to make safer return to sport clearance decisions.

CCMI baseline testing takes roughly 30 minutes per individual and costs around $60 to $100. In some cases, testing may be covered under **health insurance benefits**. All test results are stored on a secure electronic health records system that is accessible by any Complete Concussion Management partnered clinic worldwide.

The CCMI baseline test protocol consists of the following test areas:

- Concussion history, medical history, learning disabilities, psychiatric history
- Symptom score
- Orientation
- Auditory Memory
- Concentration
- Visual tracking and processing speed
- Balance (sideline measure)
- Balance – using force-plates to measure postural sway
- Reaction Time
- Strength

- Delayed Recall
- ImPACT neurocognitive testing
    - Visual word & shape memory
    - Go/No-go tests
    - Reaction Time (with cognitive processing component)
    - Effort tests

**Note: Re-testing prior to return to play also involves physical exertion testing immediately prior to conducting the baseline re-assessment. This method (testing in a physically exerted state), has been shown to be a more sensitive way of testing, revealing up to 28% more neurocognitive impairment than neurocognitive testing at rest (11,12).

Symptom Score

The Post-Concussion Symptom Score (PCSS) is the most widely used concussion symptom inventory worldwide. Adapted by the Concussion In Sport Group as part of the Sideline Concussion Assessment Tool (SCAT), the PCSS is a 22-item measure with each symptom scored on a 7-point likert scale (14). A study by McCrea et al., found that the PCSS demonstrated the most sensitive and specific measure for concussion at the time of injury (when compared to balance and a neurocognitive examination), however, fewer than 5% of athletes reported higher symptom scores than baseline at 7 days post injury(15). These findings have also been replicated in other studies(5). This indicates that the symptom score, while potentially the most useful parameter for making the initial diagnosis of concussion, does not coincide with the recovery of the brain following concussion (22 to 30 days in previous metabolic studies). Therefore, more objective testing parameters are required to inform safer return-to-play decision-making.

Standard Assessment of Concussion (SAC)

Also a component of the SCAT, the SAC is a verbal/auditory neurocognitive test, which consists of Orientation, Immediate Memory, Concentration, and Delayed Memory Recall Tests. The SAC has been validated in several studies for use in the assessment of sport-related concussion(16-18). Because the SAC does not yet have established normative data, this test must be administered at baseline to establish individualized scores(19). Barr & McCrea found that immediate SAC scores decrease in concussion patients by an average of 4 points from baseline. Using multiple regression the authors found that a 1-point decrease from baseline SAC carried a 94% sensitivity and 76% specificity for the diagnosis of concussion (20). Marindes et al., found that the SAC alone was only able to accurately diagnose concussion 52% of the time, however adding in balance assessments and the King-Devick test improved the diagnostic accuracy to 100% (21). This demonstrates that the strength of concussion assessment rests in having numerous testing parameters versus relying on one single test. This test has also been found to demonstrate objective impairment in individuals reporting a complete resolution of symptoms (15).

King-Devick Test

Originally developed for the assessment of dyslexia, the King-Devick (K-D) test has emerged as one of the most popular and useful sideline concussion tests. The K-D test is an easily administered and scored test for visual tracking and processing speed. Dhawan et al., found that following a concussion, there is an average drop from baseline score by 7.3 seconds. These deficits can also remain beyond the symptomatic period, which makes the K-D test not only a good immediate sideline test, but also a good return-to-play assessment measure (22). Marindes et al., found that the K-D test alone was able to pick up 79% of concussion injuries and when combined with balance and SAC testing, 100% of concussions were accurately diagnosed(21), once again demonstrating the value of using a multifaceted approach to concussion assessment. In healthy individuals, scores tend to improve over time due to a known learning effect; however with concussion, scores significantly worsen compared to baseline making this a valid test for distinguishing healthy vs. concussed individuals (23-25).

Balance Assessment

Complete Concussion Management Inc. performs a two-part balance assessment, which consists of the Balance Error Scoring system from the SCAT as well as a more objective measure of postural sway utilizing force-plate technology.

The BESS test has been studied extensively in the concussed population(17,26,27). Research in this area has found that the range of baseline scores in healthy individuals is quite wide and also age dependent, making the utilization of normative data questionable as a comparison(28,29). This test has been shown to be most useful for acute concussion as scores have been found to normalize within 3 days from injury(27,30). As such, the Complete Concussion Management program utilizes a secondary balance assessment examining centre of pressure measurements from force-plate technology that has been found to show deficits beyond resolution of symptoms, SAC scores, BESS, and computerized neurocognitive test scores(31). Other studies have demonstrated more sophisticated measures of balance utilizing force-plate technology can show impairments for up to 30-days following injury(32), which correlates well with previously identified physiologic recovery following concussion.

Clinical Reaction Time

This test was developed and validated by Dr. James Eckner and Dr. Jeff Kutcher, of the University of Michigan. This test is easily administered in a seated position using the athlete's non-dominant hand to grasp a dropped measuring stick with a standardized weight and spacer. This test has been found to show immediate deficits following concussion when compared to baseline (33) and has been validated against both computerized neurocognitive measures (34,35) as well as a 'functional head protective response' (the ability for an athlete to react to and protect themselves from incoming objects aimed at their head) (36), making this a useful test when determining the safety of an athlete to return to the playing field. This test has also been found to have moderate test-retest reliability over 1 to 2 seasons in NCAA athletes (37). Complete Concussion Management Inc. performs this test on a yearly basis.

Motor Strength

Tests of motor strength are currently being studied at Holland-Bloorview kids rehabilitation hospital with preliminary findings demonstrating that non-dominant hand grip strength shows concussion deficits beyond symptomatic recovery in children between the ages of 5 and 18. Complete Concussion Management is looking to contribute to this research by testing both dominant and non-dominant grip strength in all baseline assessments performed.

ImPACT®

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT®) is a computer-based neurocognitive battery. This test, comprising of visual memory tasks for shapes and words, reaction time, and basic executive function tasks, takes roughly 30-minutes to complete and is the most studied computerized neurocognitive test on the market. ImPACT has not yet been validated in ages younger than 13 years old. As such, Complete Concussion Management only utilizes this test as a part of our comprehensive battery in athletes 13 years or older. A recent study found that comparison of concussed individuals to a pre-injury baseline test is superior to using age-adjusted normative data as normative comparisons identified fewer symptomatic, concussed athletes than baseline comparisons using reliable change indices (38).

ImPACT testing has come under scrutiny in recent years as many clinicians are using this test as the sole determination of both injury diagnosis and return-to-play decision-making. Numerous studies have found poor test-retest reliability (39,40) and low- to moderate effect sizes (41), which has lead most experts to strongly oppose the use of ImPACT as a stand-alone measure for baseline and post-injury testing (14,42,43). These same statements suggest that when used as a part of a comprehensive concussion evaluation, these tests can be quite useful in the overall concussion evaluation. ImPACT testing has been shown to demonstrate ongoing impairment in 25% of individuals who have been cleared to return-to-play following sports physician clearance based on examination and passing of baseline SCAT parameters (44). ImPACT test is therefore a useful test to include as part of a comprehensive concussion testing battery both at baseline and post-injury, but should not be used in isolation.

Two recent studies have also found that high-intensity physical exertion, completed prior to test administration effects neurocognitive function (11,12). As such, the current recommendation is to perform ImPACT tests following intensive physical exertion when making return-to-play clearance decisions, as this may be a more sensitive measure of ongoing cognitive deficits. In lieu of these studies, Complete Concussion Management Inc. performs our entire testing battery following the completion of the Gapski-Goodman physical exertion test (45) prior to making return-to-play clearance decisions. Athletes must remain symptom free throughout the duration of the Gapski-Goodman Test (GGT) as well as complete ALL physical and cognitive measures (including ImPACT if 13 years or older) to a level at or above their pre-season baseline test results immediately following the GGT. If no baseline test is available, the clinician can compare results to age-adjusted normative data however this may result in less than optimal return-to-play decisions as norms are based on U.S. data and adjusted to U.S. grade point averages.

CCMI Baseline and Concussion Management Summary

Complete Concussion Management Inc. was developed from the necessity to provide high-risk athletes with evidence-based concussion management strategies. The baseline testing protocol outlined above was developed through years of research to establish the most comprehensive testing battery to assess both acute injuries and the readiness to return to high-risk sporting activities. The period of brain vulnerability prior to full recovery from concussion injuries has been shown to result in long lasting and potentially permanent or fatal outcomes should an individual suffer another concussion during this time. It has been well established through the literature that symptoms alone do not reflect true recovery of the brain, making it imperative that objective measures be incorporated into the decision-making process. In addition to this, healthcare practitioners often face pressure from athletes and/or their parents to provide clearance because the symptoms have dissipated. Having rigorous objective testing parameters can relieve this pressure and provide the clinician with the needed evidence to hold an athlete back from an early return to competition.

As was demonstrated above, no single concussion test is adequate to be used in isolation for either diagnosis or return-to-play decision-making. The Complete Concussion Management protocol conducts the most extensive concussion baseline testing available. Clearance of any athlete is not granted until there is a complete return to baseline of ALL pre-season measures following the passing of all step-wise return-to-learn and return-to-play stages including a 2-step process of physical exertion testing.

Referrals:

Concussed patients, both with and without a baseline, can be referred to any of our hundreds of partnered clinic locations around the world by downloading our PDF referral pads here (http://completeconcussions.com/for-physicians/). Complete Concussion Management facilities also provide rehabilitation for chronic concussion symptoms (i.e., headaches, vestibular/visual problems, cognitive impairments, etc.). If you wish to receive a progress report on the referred patient, please indicate this on your referral.

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